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Geological Analysis of the Main Dolomite Formations (Ca2) in Western Poland

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The Main Dolomite (Ca2) of the Zechstein has been the focus for the search of oil in Poland for several years. In this carbonate reservoir, in the area of the Gorzów Region, several minor fields of oil and gas have been discovered (e.g. gas in Cychry, Rózansko, Stanowice; oil in Jeniniec, Lubiszyn, Namyslin; and a gas-condensate field in Zielin). Drilling, which started in 1992 in the western part of the Gorzów Block, led to the discovery of a gas-oil field in the Main Dolomite Ca2 level called Barnówko-Mostno-Buszewo (B-M-B) field. The reserves are over 64 million tons of oil and 29 billion m^3 of gas. This makes B-M-B field the largest field in the country. Drilling and testing of oil from the Gajewo-1 well in 1997, which is 3.5 km (about 2.2 miles) from the northwest of the B-M-B field limits, could increase the field reserves by 10%. The purpose of this paper is to present the depositional processes and stratigraphy of the Main Dolomite, which is the largest hydrocarbon reservoir in Poland.

Depositional Conditions—The first cyclothem formation (PZ1) varies from about 110.0 meters (328.1 feet) in the open marine environment of the basin to over 300.0 meters (984.2 feet) at Zechstein paleoelevations along the northern edge of Wolsztyn Uplift. This results in considerable depth variations in the reservoir at the end of PZ1 cyclothem. The Main Dolomite (Ca2) deposition took place mainly in the area of the Gorzów Block where a carbonate platform is attached to the mainland. Four deposition intervals representing differing facies occur:

Deep Marine Interval—This part of the Main Dolomite is developed as dark grey limestone, highly clayey and sometimes slightly dolomitic. The interval can be described as a clayey mudstone facies. The Main Dolomite attains a thickness of 7 meters (23.0 feet) at elevated highs and in the Zechstein basin it turns into a schist with a thickness of 3 to 5 meters (9.8 to 15.4 feet).

Front Barrier Interval—This facies is found at the foot of a sulfate platform cyclothem PZ1 slope. It has been best recognized by wells in the region of Sulecin, Chartowo and Lubiszyn. The Main Dolomite located on the slope of the sulfate platform has been penetrated by the Lubiszyn-2 and Lubiszyn-3k wells. This carbonate is characterized by alternating limestones and dolomites with dolomites dominating. They are usually dark grey dolomites of grainstone or packstone fabric. The dolomite Ca2 thickness varies from 5 to 15 meters (16.4 to 49.2 feet). The typical feature of the front barrier dolomites is that they have a form of dolomitic breccia, such as conglomeratic to brecciated and oolitic to oncolitic dolomites. This breccia is cemented with anhydrite and salt, which makes for a low quality reservoir. Structurally, the breccia may be recognized as dolomite sediment flows from a barrier zone.

Barrier Interval—This interval forms a border between the open sea and the lagoon. This interval has been encountered in numerous wells. Dolomite thickness varies from 20 to 100 meters (65.6 to 328.1 feet). The Main Dolomite usually occurs as a dolomitized oolitic grainstone.

Lagoon Interval—This facies is usually separated from the sea by a carbonate barrier. Climatic conditions and the type of connection with the open sea created various levels of salinity. The level of salinity influenced the type of organisms living in the lagoon. The facies is characterized by isolated lagoons resulting in distinct diagenetic events which occurred almost simultaneously with sedimentation and produced early dolomitization. The upper part of the Main Dolomite drilled in the Sciechów-1 well is characterized by these conditions. Within the lagoons, shallow-water structures called internal barriers are formed (Pikulski, 1996).

The Development of the Main Dolomite Barrier Lithofacies—The analysis of the facies development of the Main Dolomite has been conducted on the basis of macroscopic and microscopic observations. The depositional conditions of cyclothem PZ1 described above influenced the development of the Main Dolomite. In the area studied, the following facies can be distinguished.

Level A—This level is usually located in the lowest part of Ca2. It is represented by crystalline dolomites. Highly developed processes of recrystallization, dissolution and anhydritization obliterate primary structural and textural features. Occasionally, oncolitic and intraclastic relics can be found. In the lowest part of this level, there are thin anhydrite stringers, which show there occurred a very slow change in sedimentation conditions. In those layers, microstyolites containing bitumen can be found. The amount of primary anhydrite is also considerable.

Level B—This level is located in the middle part of Ca2. It is formed as knobby-oncolitic grainstones, organodetrital grainstones and knobby-oncolitic mudstones which are slightly impregnated with anhydrite. Oncolitic grainstones with numerous intraclasts can also be found. Primary structural and textural features often become obliterated by aggradational neomorphism, dissolution and secondary cementation, but to a lesser extent than in level C. Sparite and sulfate cement comprise only a small part of the intergranular space volume. Numerous cavern-like interstices and crevices are usually filled with secondary anhydrite.

Level C—This level is located in the upper part of Ca2. It is represented by (1) recrystallized organodetrital oolitic to intraclast grainstones with a considerable amount of vadose cement; (2) oolitic to peloidal packstones with highly visible vadose cements; (3) algal and laminar biolothites; and (4) biolami noids with abundant anhydrite impregnation. Dissolution of carbonates and secondary sulfate cements are common. This level exhibits a very strong influence from vadose processes resulting in cements and vadose coats. These features obliterate the primary structures and textures of the rock.

Structural Characteristics of B-M-B Field Area—The Ca2str (top of strata of the Main Dolomite) seismic horizon is traced using 3D seismic data. Information concerning the structure of the area is from "The Map of Absolute Amplitude Values in Top and Base Reservoir Series of the Main Dolomite-Ca2 Composite," "The Map of Average Porosity Values in the 10 ms Interval Below Ca2str," and "The Map of Average Acoustic Impedance Values in the Interval Ca2str-Ca2sp2" (Górski and Trela, 1996). With the use of absolute amplitude attributes at the top and base of the Main Dolomite, these authors were able to use seismic inversion porosity (Górski and Trela, 1996, 1997). On the basis of the above mentioned maps supplemented with the data from B-M-B field wells, maps of inversion porosity in the interval of Ca2str-Ca2sp (base of strata of the Main Dolomite) were created (Górski et al., 1998). The maps showed that the most advantageous reservoir properties correlate with the main ridge of the oolite Ca2 barrier. These two analyses delineated the portion of the carbonate barrier buried as a result of Cimmerian orogenetic movements. This part of the barrier shows the most favorable reservoir properties and the highest probability of hydrocarbon accumulation in both structural and stratigraphic traps.

The present structural picture of the Main Dolomite shows deepening towards the northeast. Several wells have been drilled on the following structures: Barnówko and Mostno (3000.0 meters; 9842.4 feet), Buszewo (3070.0 meters; 10072.1 feet), and Gajewo (3090 meters; 10137.7 feet). In the northern part of the region, the Main Dolomite dips to depths of 3200 meters (10498.7 feet).

The southern edge of carbonate platform included the hydrocarbon migration pathway. There was a barrier to the southwest. The location of the barrier was proven by the B-M-B and Lubiszyn field discov eries. The exception is the Rózansko gas field, which is situated along the northern edge of the carbonate platform. Deposition of the Main Dolomite in the area of the Rózansko field indicates an isolated structure at the base of the barrier zone. The structural depth of the Rózansko field is 3160.5 meters (10368.9 feet) which is structurally lower than B-M-B (3107.0 meters; 10193.5 feet) or Lubiszyn (3085.0 meters; 10121.3 feet) fields. The fact that there are different structural positions indicates that there are numerous lithological boundaries within the carbonate platform (Pikulski, 1996; Górski and Trela, 1997; Pikulski and Protas, 1997).

Characteristics of the Main Dolomite Paleomorphology—Continuous drilling of the largest gas and oil fields in Poland (B-M-B field) and the use of the latest computer techniques has made it possible to prepare a detailed paleostructural analysis of the area. The basal part of the C level is characterized by the maximum concentration of vadose cements with the saline-anhydritic level above the basic anhydrite (A2). This is one of the most important determinants of paleomorphology and of deposition of the Main Dolomite. The Main Dolomite carbonate barrier developed gradually. The present structural configuration at this level is different from the one presented on the paleostructural map. The latter shows that the main barrier ridge (at first consisting of unconsolidated carbonate sands) was located along the northern edge of the sulfate platform. The barrier ridge continues from the Barnówko elevation towards the east, adjacent to the Buszewo-8 and Gajewo-1 wells, and further to the Sciechów-1 and Podlesie-1 wells. In the area of Gorzów Wlkp, the barrier ridge divides into two secondary ridges which join south of the Gorzów Wlkp-1 well (Pikulski, 1996; Pikulski and Protas, 1997). In order to depict the basin morphology of the Main Dolomite at the end of its deposition, a 3D block diagram has been drawn. Many of the characteristic morphological elements connected with the carbonate platform sedimentation are illustrated in this diagram (Pikulski, 1997). There are semi-circular (Barnówko) or ribbon (Gjewo-Dzikowo) barriers which are characterized by the dynamics of high sedimentation rates.

An example of other barrier forms, such as the internal barrier sequence located along the southern edge of the sulfate platform PZ1 (Mostno-Buszewo-Lubiszyn and to Dzieduszyce-Stanowice-Raclaw), are interpreted. In the central portion of the lagoonal zone, several small topographic highs have been inter preted, where internal barriers develop in the lagoonal zone.

The Main Dolomite series found in the Buszewo-7, 8 wells may be considered barriers, but their oncolitic nature proves they were formed in a deeper marine environment than typical oolitic sands. This leads to the conclusion that the main ridge of the carbonate paleobarriers were located in the vicinity of the above mentioned wells. The comparison of porosity and permeability in the wells drilled within the B-M-B field shows that the best reservoir properties exist in the Main Dolomite in the area of Buszewo-8 and Gajewo-1 wells, although on structural and facies maps the area is located in the lagoonal zone.

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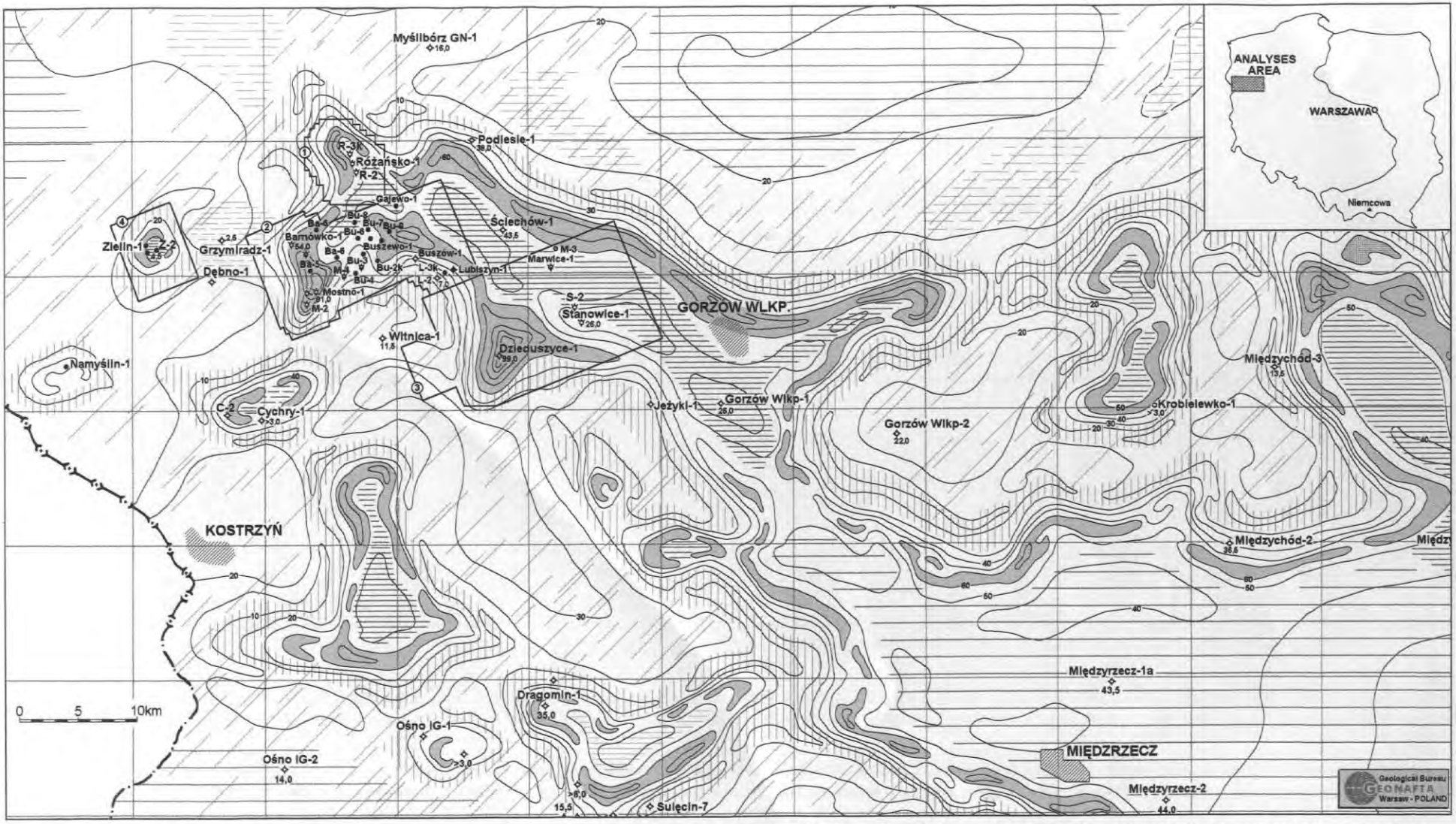

zone of deep shelf; shallow shelf (probable zones of source rock); lithofacies of the dolomite: transitional zone; barier zone; zone of inner lagoons; Well: gas producing; oil producing; gas and oil producing; abandoned; 26,0 thickness of the Main Dolomite; Area of 3D-seismic performed: ① Różańsko ② Barnówko - Lubiszyn ③ Dzieduszyce - Stanowice ④ Zielin;

Lithofacial map of the Main Dolomite forms in the area of the Gorzów Wielkopolski